AFQTP 3E0X1-21
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AIR FORCE

QUALIFICATION TRAINING PACKAGE (AFQTP)

for

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 21

MOTORS AND MOTOR CONTROL CIRCUITS

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MODULE 21

MOTORS AND MOTOR CONTROL CIRCUITS

Career Field Education and Training Plan (CFETP) references from 1 Apr 97 version.

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Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

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INTRODUCTION

Before starting this AFQTP, refer to and read the "Trainee/Trainer Guide" located on the AFCESA Web site **http://www.afcesa.af.mil/.** This guide will be found at each AFS's AFQTP download page.

AFQTPs are mandatory and must be completed to fulfill task knowledge requirements on core and diamond tasks for upgrade training. ***It is important for the trainer and trainee to understand*** that an AFQTP ***does not*** replace hands-on training, nor will completion of an AFQTP meet the requirement for core task certification. AFQTPs will be used in conjunction with applicable technical references and hands-on training.

AFQTPs and Certification and Testing (CerTest) must be used as minimum upgrade requirements for Diamond tasks.

MANDATORY minimum upgrade requirements:

Core task:

AFQTP completion
Hands-on certification

Diamond task:

AFQTP completion
CerTest completion (80% minimum to pass)

Note: *Trainees will receive hands-on certification training when equipment becomes available either at home station or at a TDY location.*

Put this package to use. Subject matter experts under the direction and guidance of HQ AFCESA/CEOF revised this AFQTP. If you have any recommendations for improving this document, please contact the Electrical Career Field Manager at the address below.

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MOTORS AND MOTOR CONTROL CIRCUITS

MODULE 21 — AFQTP UNIT 1

INSTALL MOTORS (21.1.)

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INSTALL MOTORS

Task Training Guide

STS Reference Number/Title:	21.1. – Motors and motor control circuits, install motors
Training References:	• CDC 3E051B, Vol. 2 • National Electric Code, Article 430
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool kit • Phase rotation meter
Learning Objective:	• Given equipment, install a motor
Samples of Behavior:	• Follow the required steps to install a motor • Know the safety requirements to install a motor
Notes:	
• Any safety violation will result in an automatic failure.	

INSTALL MOTORS

Background: In our automated world, we take for granted one of the most efficient devices ever invented—the electric motor. About 98 percent of industry use motors. The average home application has increased over the past few years, ranging from small clock motors to large heating and air-conditioning motors. The rotating device that converts electrical energy into mechanical energy is the *electric motor*. Nearly all motors are designed to meet the requirements of a specific function. All electric motors fall into these basic types:

- Alternating current (AC).
- Universal.
- Direct current (DC).

We will discuss the AC and universal motors, as well as, the installation procedures for each. The basic types of three-phase motors are *induction* and *synchronous*. Both motors depend on a rotating magnetic field for operation. The construction of the rotor is the basic difference between these AC motors. We'll cover only the induction type. The most common types of three-phase induction motors are the squirrel-cage rotor and the wire-wound rotor (also called an armature). Three-phase motors, sometimes termed "polyphase motors," have these basic parts:

- Stator.
- Rotor.
- Endbells.

The motor housing or frame (Figure 1), serves to house the stator, which contains the stationary windings, and provides an attachment point for the supply voltage. The stator is made of cast iron or steel and has a silicon steel core pressed inside. The steel core is made with semi-closed slots that hold the field windings. The field windings are made up of many varnish-insulated coils separated by 120 electrical degrees, or 1/3 cycle of AC power. The coils are insulated from the core with treated paper called fish paper. The coils are connected to form three separate windings. The field windings and the steel core together make up the stator part of the motor.

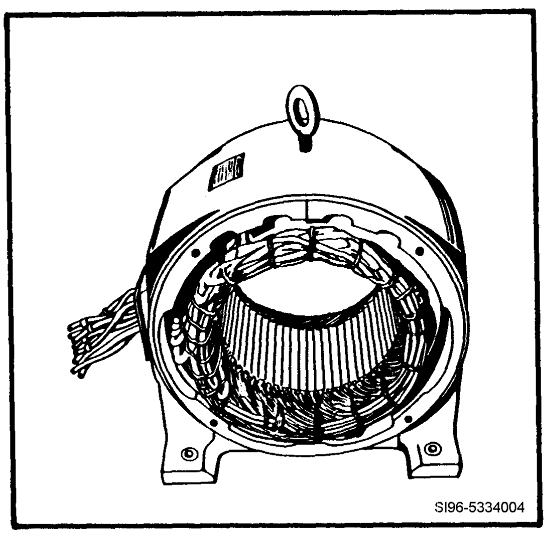

Figure 1, Three-Phase Stator

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The rotor is the rotating part of the motor. The rotor provides the conversion of electrical energy to mechanical energy by attaching the motor to the load. Rotors may be either the wire-wound or squirrel-cage type, depending on the manufacturing and motor requirements.

Squirrel-cage rotors are cheaper to build and need less maintenance than the wound rotor. The squirrel-cage rotor is a laminated iron core mounted on a spider or framework secured to the shaft (Figure 2). Bars of copper, aluminum, or any alloy that is a good conductor, are laid in slots in the core. All the bars are connected to end rings forming a complete current path. Smaller motors, less than 1 horsepower (hp) may have the rotor cast in one piece and the rotor bars are on an angle to the shaft. This is called *skew*, and the effect increases the torque of the motor. Squirrel-cage rotors do not have electrical connections from the power source, insulation, commutator or sliprings. The rotor bars and end rings make up a squirrel-cage winding. Fan blades are added on the end of the rotor for ventilation.

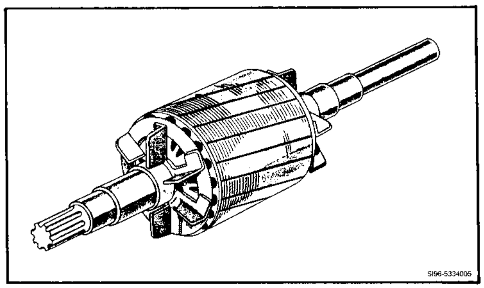

Figure 2, Squirrel-Cage Rotor

The wound rotor in Figure 3 has a laminated silicon steel core mounted on a shaft. Instead of rotor bars the rotor has windings are made of coils of copper wire similar to those used in the stator. The windings are connected, wye or delta; and the other ends of the windings are connected to sliprings and externally to resistors for variable speed control and low starting current.

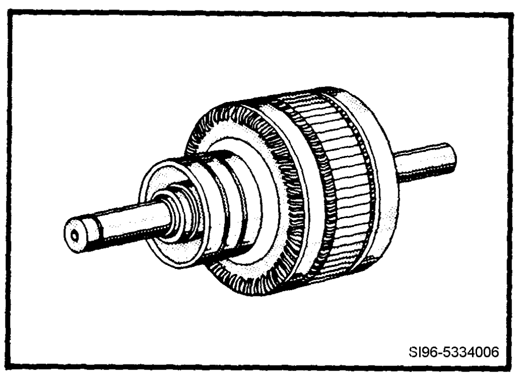

Figure 3, Three-Phase Wound Rotor

The endbells serve three functions. They house the bearings, support and align the rotor and shaft, and complete the frame of the motor.

A three-phase induction motor depends on a rotating magnetic field for operation. When current flows through the stator windings, a rotating magnetic field is produced that induces a voltage in the rotor. The current flow in the rotor sets up a magnetic field that is attracted to the rotating field in the stator. When the current reaches its maximum value in one winding, the winding produces a strong magnetic field. As the current in the first winding decreases, the current in the next winding increases, causing the magnetic field to move to that winding. As the current decreases in the second winding, it increases in the third winding, causing the magnetic field to move again. The windings are distributed so that this rotation of the magnetic field is uniform and continuous. Notice how the magnetic field rotates around the stator in the lower part of Figure 4. These magnetic fields cut across the rotor, inducing voltage in the rotor. This voltage causes a current to flow in the rotor that produces a magnetic field. Since the voltage is induced, the magnetic field in the rotor is opposite to the magnetic field that produced it. The unlike poles from the rotor follow those produced in the stator and rotation is developed.

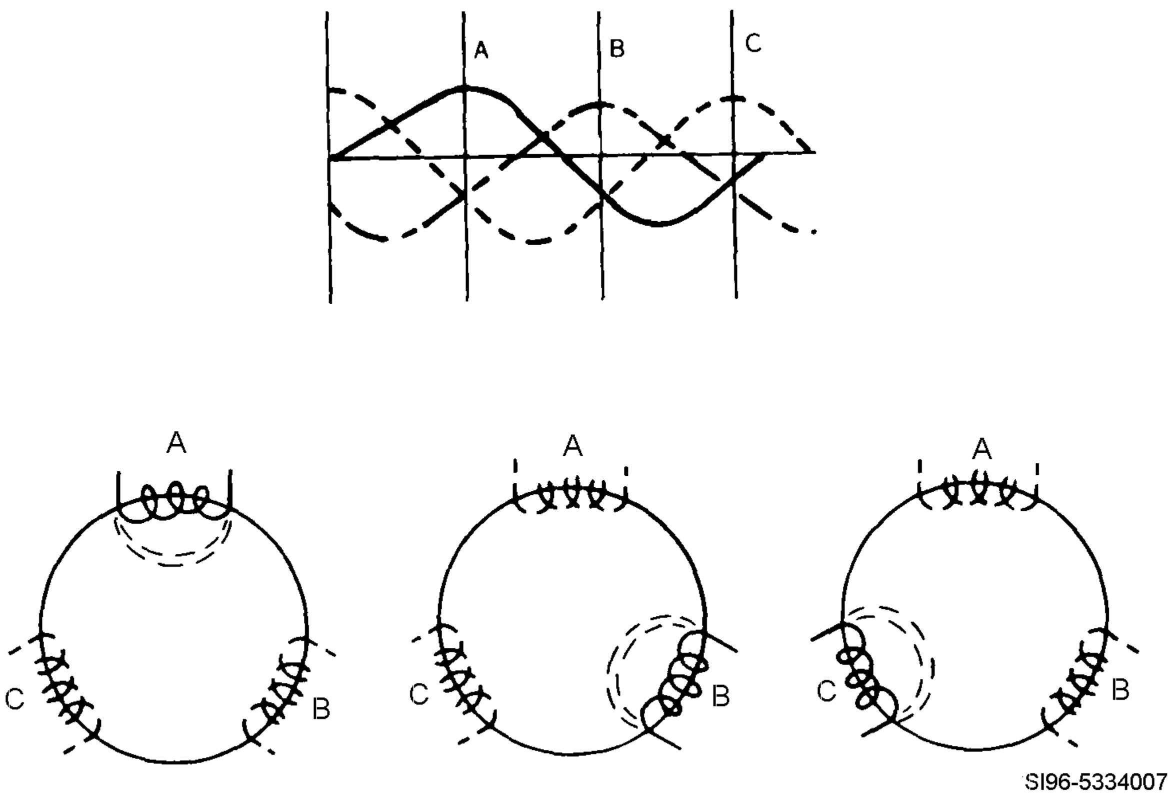

Figure 4, Rotating Magnetic Field Schematic

Three-phase motors have both internal and external connections to the stator coils. These coils are connected to each other internally to produce three separate windings or phases in the stator. The internal windings of all three-phase motors have either a wye or delta connection. The external connections are made with the leads that are brought out of the motor and connected to power. Some three-phase motors are single voltage and others are dual voltage. This tells us that the single-voltage motor operates at one particular voltage (for example, 220 volts). The dual-voltage motor can operate at two different voltages (for example, 220 or 440 volts), depending on how external connections are made. A single-voltage, three-phase motor requires only three leads to be brought out. A dual-voltage, three-phase motor normally has nine leads coming out of the motor. Each lead is one end of a stator coil that is numbered for identification. An example is shown in Figure 5. In the top right corner look at the schematic of one coil numbered 1 and 4. Let's call these leads 1–4. The coil just below 1–4 would be 7–10, which is the second half of single-phase winding. Connect these coils in series for high voltage or parallel for low voltage.

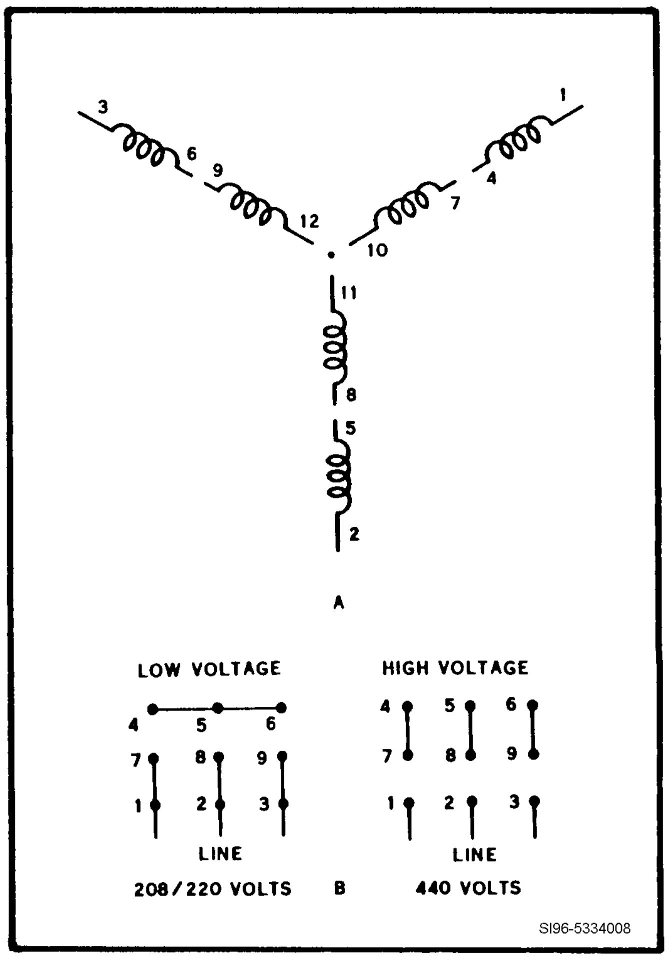

Figure 5, Three-Phase Wye Connections

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The symbol for a wye-connected motor is Y, sometimes referred to as a "star." Figure 5 shows a schematic diagram of a wye-connected dual-voltage motor. Leads 10, 11, and 12 are the ends of three separate coils connected together (normally the manufacturer completes this inside the motor). These leads are the internal connections that form the Y. The remaining nine leads are brought out of the motor for the external connections. Notice in the figure that 208/220 volts is low voltage, and 440 volts is the high voltage. This information is given on the motor data plate, which we'll discuss later in this unit.

The symbol for a delta-connected motor is the Greek letter delta (Δ). Figure 6 shows a dual-voltage, delta-connected motor. Leads 10, 11, and 12 are connected inside the motor to leads 1, 2, and 3 respectively. Leads 1 through 9 are brought out in the terminal box of the motor.

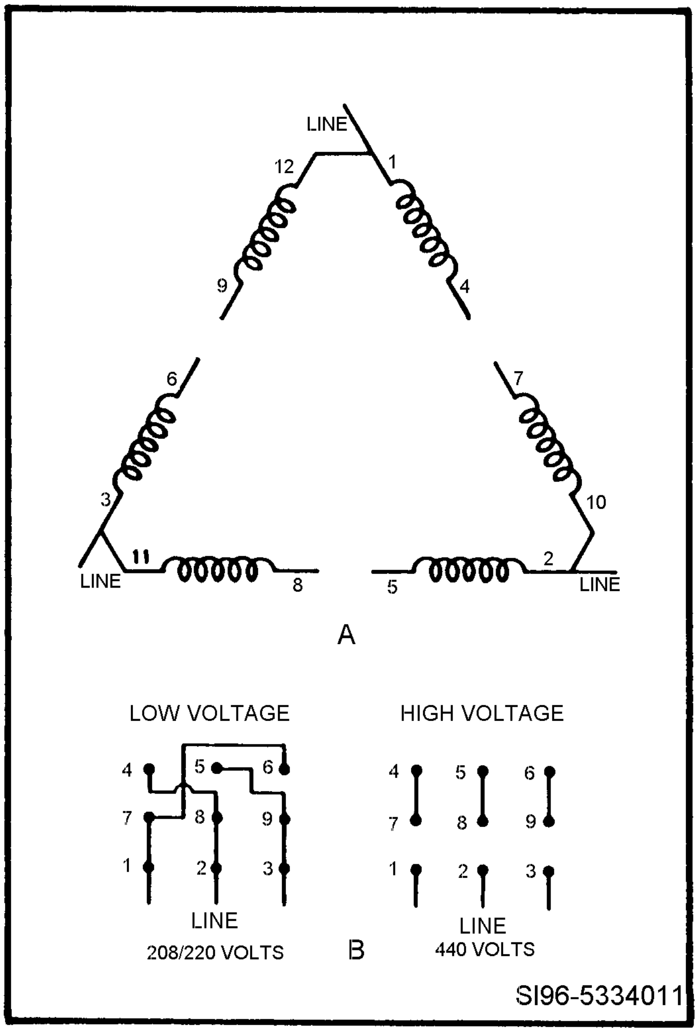

Figure 6, Three-Phase Delta Connection

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Single Phase Motors

Most of the motorized appliances and machines found in the home are equipped with single-phase AC motors. Single-phase motors range from a fraction of a horsepower up to 10 hp. However, you'll rarely find one over two (2) horsepower. Single-phase motors are divided generally into two classes: commutator and induction. Let's begin with the induction type. Of all AC motors, the induction motor is the most widely used. Its design is simple and sturdy. One of the major differences between a single-phase and a three-phase motor is that the single-phase motor requires some starting means, whereas the three-phase motor does not.

Split-phase motors are usually just fractional horsepower and are used to operate such devices as washing machines, small pumps, dryers, and blowers. Basically, a split-phase motor is constructed the same as a three-phase motor. It has a stator, squirrel-cage rotor, and two endbells. The windings, however, are located and connected differently than they are in a three-phase motor. Also, a centrifugal switch is used during starting (Figure 7). A rotating part of the centrifugal switch is located on the rotor, and a stationary part (containing a set of contacts) is located in the endbell.

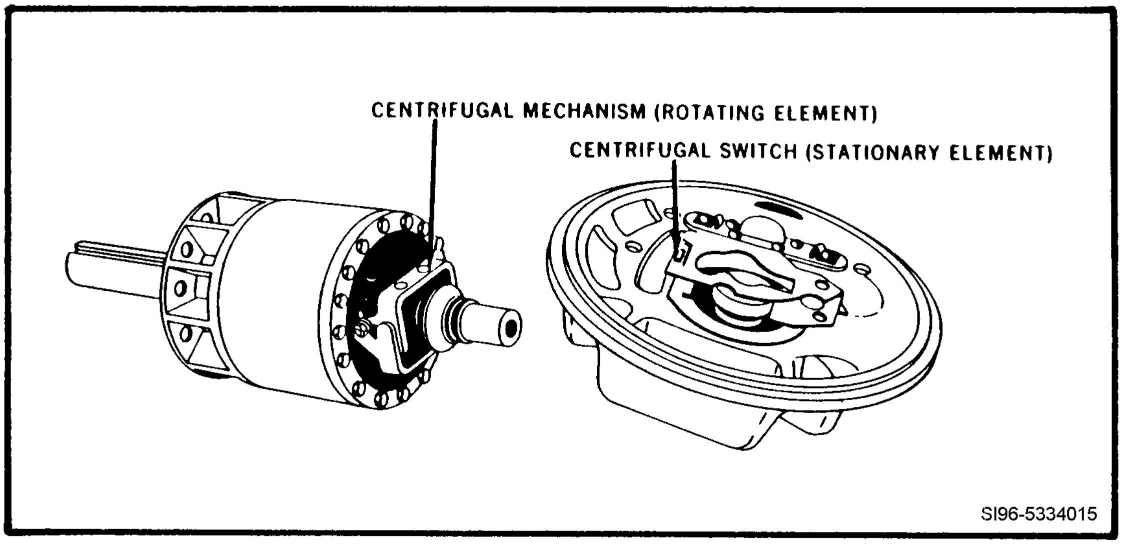


Figure 7, Components of a Centrifugal Switch

The rotating part of a centrifugal switch is a mechanism that relies on motion and flyweights to operate. As the rotor turns, the flyweights are pulled out by centrifugal force. This applies pressure to the closed contacts of the switch, causing them to open. These contacts are in series with the start winding. The opening of the contacts de-energizes the start winding after the rotor reaches a predetermined rpm.

Figure 8 is a schematic diagram of a split-phase motor. The split-phase motor has two windings. One winding is located at the bottom of the slots in the stator and is called the run winding or the main winding. The other winding is called the start winding and is located in the stator centered between the coils of the run winding. The start winding and the run windings are connected to power until the motor reaches 75 percent of its maximum rpm. A centrifugal switch then disconnects the start winding from the power. The run winding is many turns of heavy copper wire; the start winding is fewer turns of smaller wire. If the start winding is not disconnected after a short period of time, it will burn up. When voltage is applied to both the start winding and run winding, the current in the run winding lags the voltage more than the current in the start winding. This creates a rotating magnetic field inside the stator.

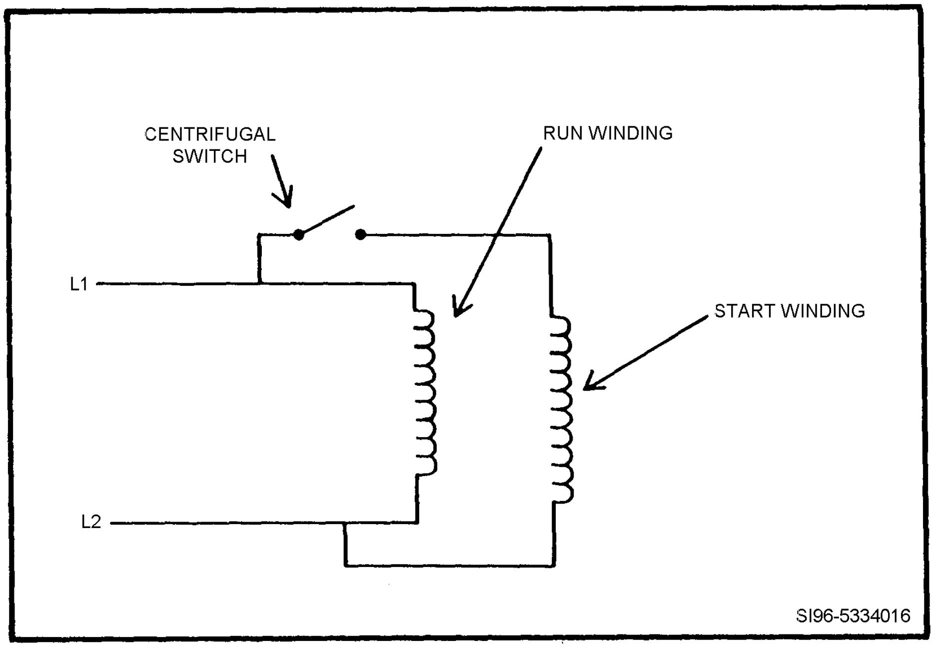


Figure 8, Split-Phase Motor Schematic

The rotating magnetic field induces a current in the rotor, which sets up an opposing magnetic field. The magnetic fields combine in such a manner causing rotation of the rotor. The start winding is used only for starting the motor. After the rotor reaches a certain rpm, the centrifugal switch disconnects the start winding. After the start winding is cut out, the motor operates on a shifting magnetic field. The run current is shifting from positive to negative and back to positive.

A capacitor-start motor (schematic diagram in Figure 9) is an improved version of the basic split-phase type of motor. The only difference is that an intermittent type of capacitor is connected in series with the start winding. When the motor reaches 75 percent of full speed, the centrifugal switch cuts out the start windings and the capacitor. The capacitor and the start windings give the motor a greater starting torque than a basic split-phase motor.

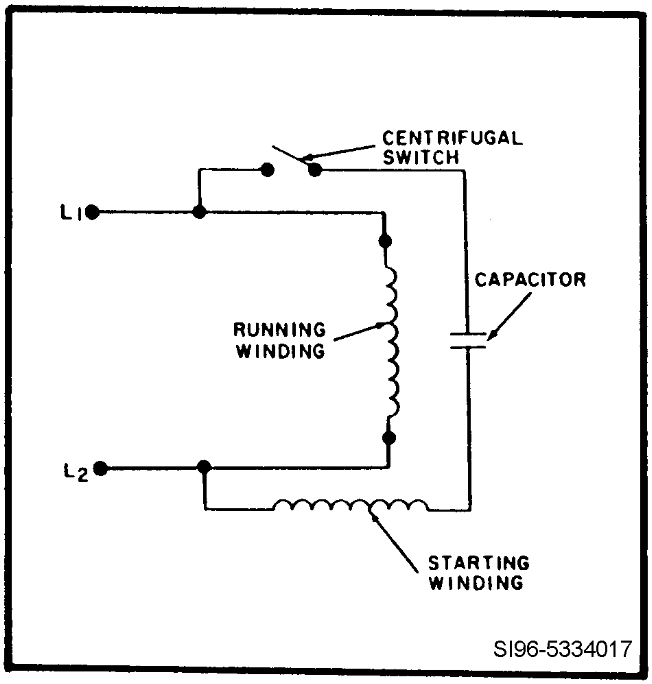


Figure 9, Capacitor-Start Motor Schematic

To create a high starting torque in a capacitor-start motor, a stronger rotating magnetic field is established inside the motor. This is accomplished by causing the current to peak at different times in the start and run windings. This is also referred to as "phase splitting". A capacitor is used, causing the current in the start winding to reach its maximum value before the current in the run winding reaches its maximum. Actually, the capacitor causes the current in the start winding to lead the current in the run winding. This causes a revolving magnetic field in the stator that induces a current in the rotor and causes it to rotate. Remember, when the motor stops, the centrifugal switch contacts will close by spring pressure so that the motor can be started again. Capacitor-start motors are furnished usually in ratings from 1/6 to 1 hp and are used on pumps, fans, and machine tools.

The permanent-split capacitor motor has a standard split-phase-type stator, a squirrel-cage rotor, a capacitor, and endbells. This is another version of the basic split-phase motor. A permanent-type capacitor is connected in series with the start windings and left in the circuit at all times (Figure 10). The start windings in this motor are not high-resistance windings and have the same number of turns and wire size as the run windings. The capacitor is used instead of resistance to give the split-phase effect. This eliminates the need for a centrifugal switch in this motor. The capacitor is continuously rated and is selected to give best operation at full speed while sacrificing starting torque. The permanent-split capacitor motor has the operating characteristics of poor starting torque with a good running torque under load conditions.

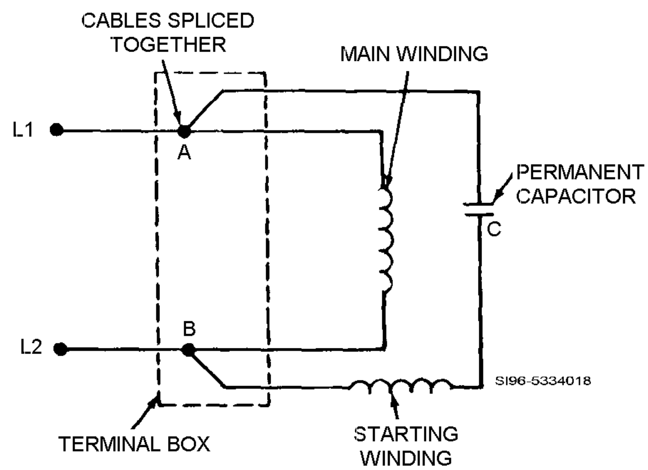


Figure 10, Permanent-Split Motor Schematic

A universal motor is one that can operate on either single-phase AC or DC power. Normally, these motors are made in sizes for special conditions. You use the fractional horsepower sizes on vacuum cleaners, sewing machines, food mixers, and power handtools. There are several types of universal motors; however, the salient-pole type is more popular than the other types. The salient-pole type has a stator with two concentrated field windings, a wound rotor, a commutator, and brushes. The stator and rotor windings in this motor are connected in series with the power source. There are two carbon brushes in this motor that remain on the commutator at all times. These two brushes are used to connect the rotor windings in series with the field windings and the power source. See the schematic in Figure 15.

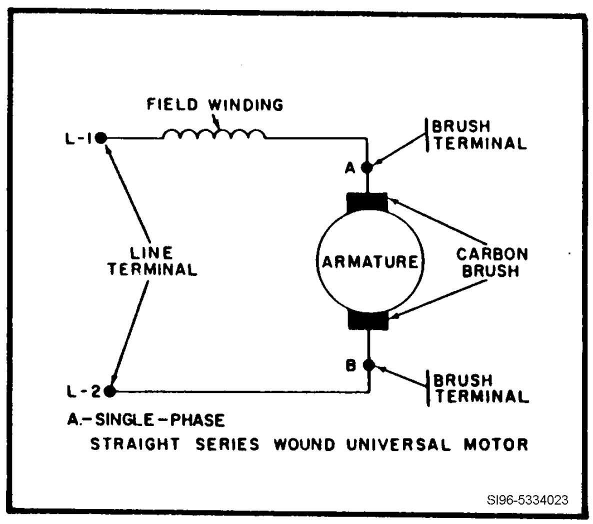


Figure 15, Universal Motor Schematic

The universal motor does not operate at a constant speed. The motor runs as fast as the load permits, low speed with a heavy load and high speed with a light load. Universal motors have the highest horsepower-to-weight ratio of all electric motors. The operation of a universal motor is much like that of a series DC motor. Since the field winding and armature are connected in series, both the field winding and armature winding are energized when voltage is applied to the motor. Both windings produce magnetic fields, which react to each other and cause the armature to rotate. Either AC or DC power causes the reaction between these magnetic fields.

Motor Installation

Before you can install a motor, many factors need to be considered if trouble-free operation is to be expected. The physical location of the motor affects the type of motor housing (enclosure) required. A different type motor enclosure is required to protect a motor that is exposed to rain as compared to one installed in a dry location. Ensuring the proper selection provides a trouble-free installation. Some of the common enclosures used for different environmental conditions are:

ENCLOSURE	DESCRIPTION
Open	This motor has ventilating openings in the frame that permit the passage of outside air to cool over and around the windings.
Splash-proof	This is an open motor in which the vent slots are made to prevent liquids or solids from entering them except at indirect angles.
Totally enclosed	This motor is built to prevent free passage of outside air. It is not airtight; therefore, it cannot be used in an explosive area.
Dripproof	This is an open motor in which the ventilating openings are constructed so that drops of liquids or solid particles falling on the machine either directly or by striking and running along a horizontal surface will not enter the motor.
Waterproof	This is a totally enclosed motor constructed so that it prevents water from entering even if applied in the form of a stream from a hose.
Explosion-proof	These motors are designed to withstand an internal explosion of the vapors or dust from the area in which they are used and to prevent an explosion due to motor faults.

Along with the type of enclosure you select, you must consider the ambient (surrounding) temperature. The ambient temperature must not exceed that listed on the motor. In general, maximum ambient temperature is 40°C or 104°F for any motor, unless the motor is designed for a different degree rating.

Another important factor to consider when selecting a motor is its function or duty. Is the motor expected to run continuously or intermittently? A continuous-duty motor is designed to operate at full load for 24 hours a day if necessary. The intermittent-duty motor is designed for frequent starting and stopping. It has construction features built in that dissipate heat rapidly. This is an important factor in the selection of motors since motor windings heat rapidly during starting.

The types of bearings used in a motor usually depend on its application to a load or its mounting plane, whether horizontal or vertical. As a general rule, sleeve-bearing motors are mounted horizontally and ball or roller-bearing motors are designed for vertical or horizontal mounting.

The voltage available to the motor must be considered when selecting a motor. The power supply must have the required phases and voltage to run the size motor available.

The connection between the motor shaft and the load that it drives is made in different ways depending on the load. The most common methods for attaching the shaft to the load are by using pulleys, couplings, and gears.

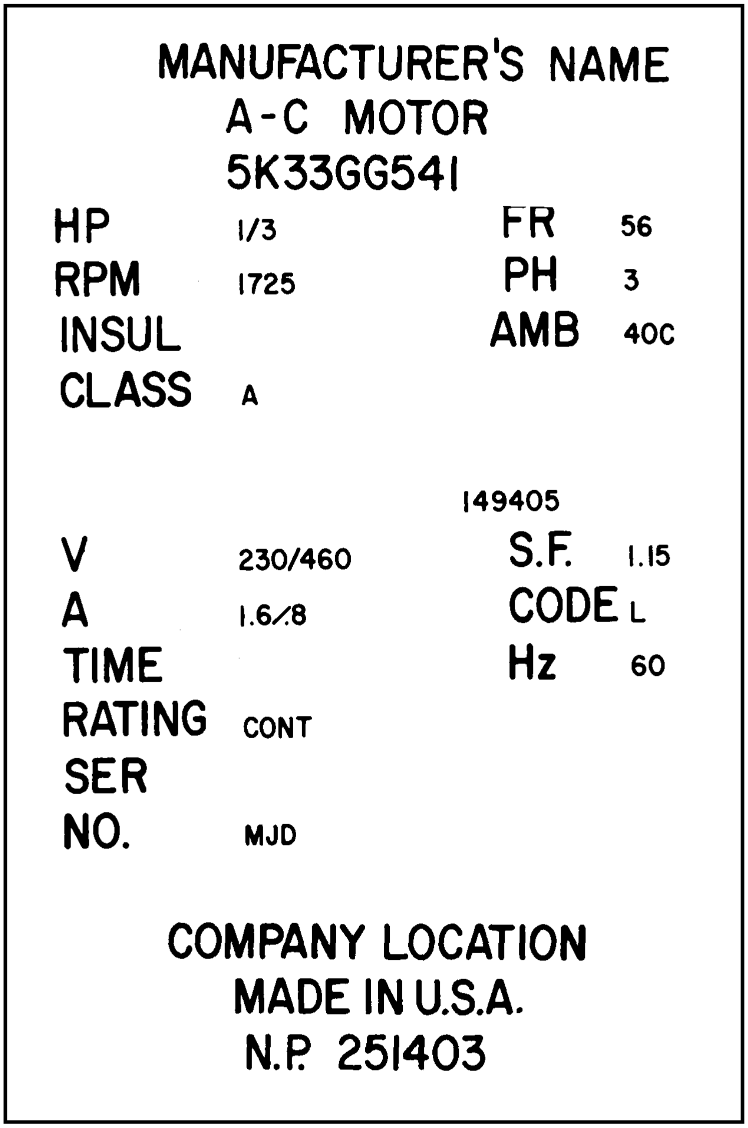
According to the NEC®, every motor must be equipped with a data plate as shown in Figure 16. This data plate must be marked with certain information pertinent to the motor.

This information is necessary in determining circuit requirements for installing motors. Listed below, in no specific order, is the information required on a motor data plate:

- Maker's name.
- Rated volts and full load amperes (amps). These show the motor's operating voltage and the current the motor draws under full load. Normally, these are expressed as V for volts and A for amps.
- Rated frequency and number of phases. These show the motor's operating frequency (marked) as hertz (Hz) and the required phases to operate the motor (marked) as (pH).
- Rated temperature rise of the insulation system and rated ambient temperature. This is the motor's maximum operating temperature under normal conditions. Normally, this is listed on a motor data plate as rise 40°C or Amb 40°C.
- Rated full load speed. This shows the rpm of a motor under full load condition. For example, rpm 1725.
- Time rating. This tells if the motor is a continuous or intermittent type.
- Code letter. The code letter gives the total kva per horsepower that the motor will draw if the rotor locks. This is found in Table 430-7(b). This becomes important when sizing the branch circuit overcurrent protection device. Code L is shown in Figure 16.

Design letters and code letters are NOT the same.

- Design Letter. Design letters reflect characteristics inherent to motor design such as lock rotor current, slip at rated load, and starting torque.
- Rated horsepower (hp) (if 1/8 or more). This determines circuit switch sizes; for example, hp 1/3. Along with required information, some manufacturers furnish data plates with useful information, such as the frame number and service factor. The frame number gives the physical dimensions of a motor; for example, shaft size, mounting configuration, keyway size, and the overall dimensions of a motor. Frame numbers are standardized, regardless of manufacturer. This information is shown on the data plate as frame or FR. The service factor is the amount of overload a motor can safely carry without damage to the unit. This is determined by multiplying the normal horsepower by the service factor. For example, a 1/3-hp motor with a service factor of 1.15 can carry a continuous load of 0.38 hp (1/3 times 1.15). The normal service factor of most motors is 1.15. This information is found on the motor data plate, normally expressed as SF.



SI96-5334036

Figure 16, Motor Data Plate

To perform the task, follow these steps:

> **NOTE:**
> The letters B through E designates standard designs for three-phase motors. Some designs offer high starting torque, while others offer low starting torque. The design should be a factor when choosing a motor for a particular job.

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

Step 1: Choose your motor.

- Choose the design.
- Select the power supply. The available power supply must have the required phases, appropriate voltage, and current capacity to start and run the size motor needed to drive the load.

> **NOTE:**
> Many motors offer dual voltage connections for high and low voltages. If both voltage values are available; the higher rating should be used. The higher voltage connections produces lower current demands on the supply circuit, and with lower current demands, smaller wire sizes may be used in the circuit, producing a savings in the cost of the installation.

- Select size. The National Electrical Manufacturer's Association (known as NEMA) classifies motors according to size; as either being fractional horsepower or integral horsepower.
- Choose the type of enclosure depending on the environment in which the motor will be placed.
- Consider the length of time the motor will operate. A continuous duty motor means the motor is expected to carry the load for at least three hours or more. Intermittent duty rated motors carry a time rating generally 5, 15, 30, or 60 minutes.

Step 2: Determine full load current of the motor.

- Find the full load current (FLC) of the motor.

> **NOTE:**
> Article 430-6 of the NEC states: For the purpose of conductors and short circuit protection, the full load current values from the NEC tables will be used instead of the motor's data plate.

- To find the FLC, first look at the data plate and find the operating voltage and the motor's HP rating.
- Second, cross-reference this information to the appropriate table, 430-148 for single phase, and 430-150 for three phase.
- The tables will give the FLC that you will refer to for fuse and conductor sizing.

Step 3: Find the fuse size.

- Use table 430-152 to find the fuse size.
- First, find your motor type, including motor design at the left-hand side of the table.
- Second, find the column to the right that represents the type protection device you will be using, follow that column down until it lines up with your type motor and note the percentage value.
- The percentage value found is multiplied by the FLC obtained from the FLC tables of the NEC.

NOTE:
Standard sizes of overcurrent protection are located in Article 240-6. If the size protection calculated is not a standard size then NEC Article 430-52 Exception 1 allows you to use the next higher standard size.

Step 4: Choose conductor size.

- Choose the conductor size, using the NEC. Article 430-22 states that a conductor supplying a single motor must be able to handle 125% of the FLC as determined by the tables of the NEC.
- Find a conductor that is within the limits of the ampacity calculated using tables 310-16 through 310-19.

Step 5: Choose conduit size.

- Determine the conduit size once you have determined your conductor size. This information is covered in chapter 9 of the NEC.

NOTE:
If all the conductors that are to be pulled into a conduit are the same size then a quick glance at tables in appendix C of the NEC will tell how many will fit in the different types of conduits ranging from ½ to 6 inch. If the conductors are not the same in all respects then you must use tables 4 through 8 in determining the correct conduit size. These tables may be found in chapter 9 of the NEC.

Step 6: Install circuit.

- Check the power supply for phase rotation.
- Mark the conductors according to phase rotation.
- Run the conduit and conductors from the power source to the location of the motor.
- All fittings must be tight and of the proper type.
- Boxes must be mounted correctly and all openings must be sealed.
- The motor should be properly aligned to ensure a long trouble free life.

NOTE:
If any safety guards are removed during installation, they should be replaced before test running the motor.

SAFETY:
DO NOT CONNECT THE CONDUCTORS TO THE POWER SOURCE UNTIL YOU HAVE FINISHED MAKING ALL THE CONNECTIONS AT THE MOTOR.

Step 7: Make motor connections (Three-phase wye-connected motor for high voltage).

- Figure 17 shows a schematic diagram of a wye-connected motor for high voltage.
- Connect any equipment grounding conductor(s) first.
- For high voltage, leads 4–7 are spliced together and taped, the same as 5–8 and 6–9.
- Connect the 440-volt 3-phase power source to leads 1, 2, and 3. Each phase is connected separately and taped. For example, the A phase of power is connected to lead 1 of the motor. Thus, the windings are electrically connected in series for high voltage.
- Go to Step 13.

NOTE:
Before making your final connections on a three-phase motor, always be sure to have the correct phase rotation to prevent damage to equipment.

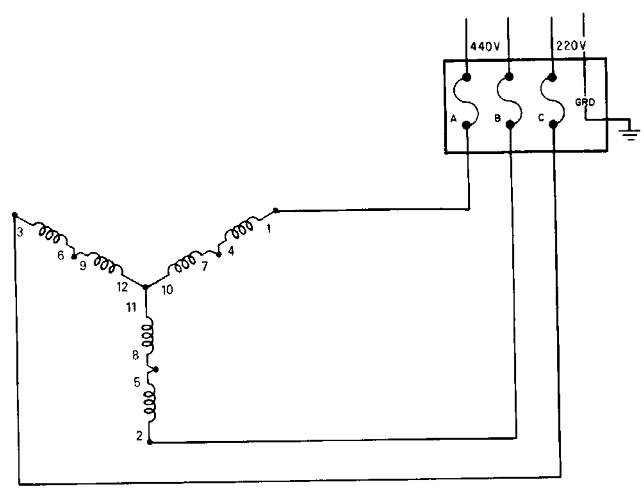


Figure 17, Three-Phase Wye-Connected Motor For High Voltage

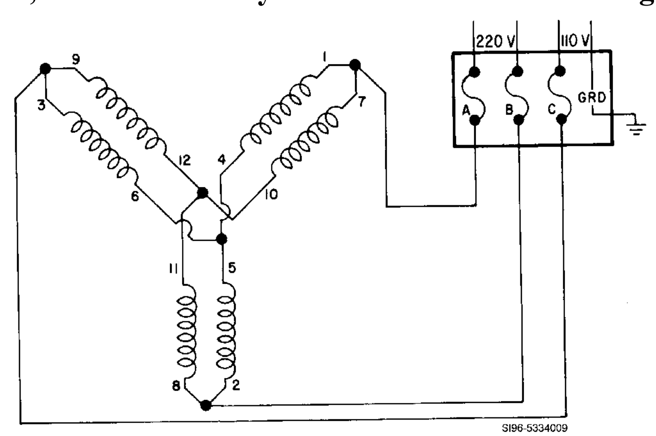


Figure 18, Three-Phase Wye-Connected Motor for Low Voltage

Step 8: Make motor connections (Three-phase wye-connected motor for low voltage.)

- Figure 18 shows a three-phase wye-connected motor for low voltage (208/220 volts).
- Connect any equipment grounding conductor(s) first.
- Second, connect any grounded conductor(s).
- Splice leads 4, 5, and 6 together and tape the connection.
- Splice leads 1–7 together and connect to one of the leads of the three-phase power source.
- Respectively, leads 2–8 and 3–9 are spliced and connected to the other two power source leads.
- Go to Step 13.

NOTE:
Windings 1–4 and 7–10 are in parallel as well as 2–5 and 8–11, and 3–6 and 9–12. Placing these windings in parallel causes the impedance of the windings to decrease. If you recall your study of Ohm's law, when resistance decreases, current increases; therefore, when a motor is connected for low voltage, it draws more current than if connected for high voltage.

Step 9: Make motor connections (Three-phase delta-connected motor for high voltage).

- Figure 19 shows a schematic diagram of a delta-connected motor for high voltage (440 volts).
- Connect any equipment grounding conductor(s) first.
- Connect leads 4–7 together and tape the connection.
- Leads 5–8 and 6–9 are also spliced and taped.
- Leads 1, 2, and 3 are connected to the power source. This configuration has the windings placed in series for high voltage.
- Go to Step 13.

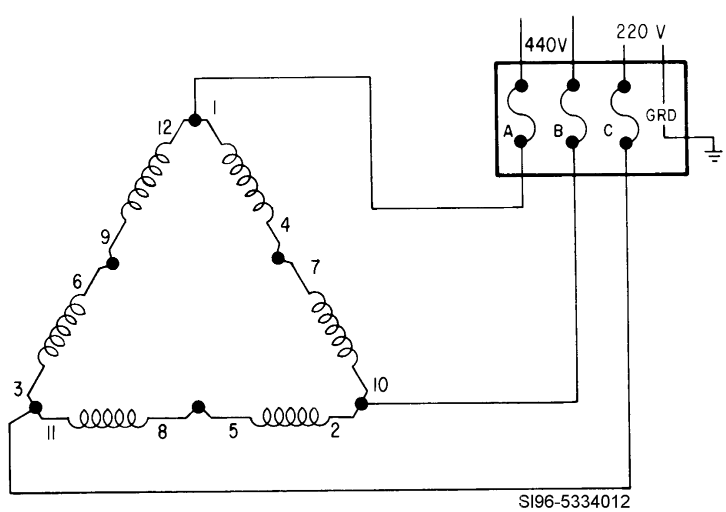


Figure 19, Three-Phase Delta-Connected Motor for High Voltage

Step 10: Make motor connections (Three-phase delta-connected motor for low voltage).

- Figure 20 shows a schematic diagram of a delta-connected motor for low voltage.
- Connect equipment grounding conductor(s) first.
- Connect leads 1–6–7, 2–4–8, and 3–5–9, placing the windings in parallel.
- Connect each of these previous connections to the power source.
- Remember, leads 10, 11, and 12 are connected inside the motor to leads 1, 2, and 3.

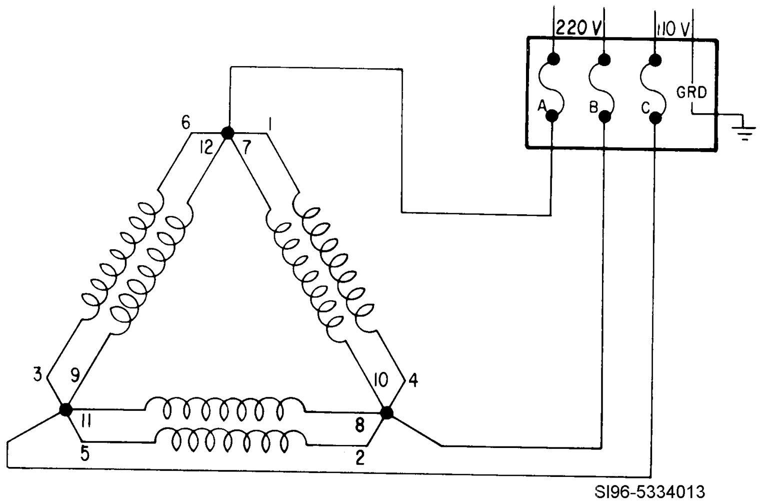


Figure 20, Three-Phase Delta-Connected Motor for Low Voltage

Step 11: Make motor connections (Single-phase, dual voltage reversible motor for high voltage). (See Figure 21 for high voltage connections).

> **NOTE:**
> The single-voltage, non-reversible-type AC motor has only two leads, T1 and T2. The single-voltage reversible motor has four leads numbered T1, T2, T5 and T8. A dual-voltage non-reversible motor has four leads numbered T1, T2, T3, and T4. The dual-voltage reversible motor leads are numbered T1, T2, T3, T4, T5, and T8. Usually, leads numbered 6 and 7 are terminals of coils connected internally.

- Connect equipment-grounding conductor(s) first.
- Second, connect grounded conductor(s).
- To operate a dual-voltage motor on high voltage, connect the run windings in series as shown in Figure 21.
- Leads T1 and T2 go to one set of windings, while T3 and T4 go to another set.
- Connect T2 and T3 together connecting the run windings in series for 240-volt use.

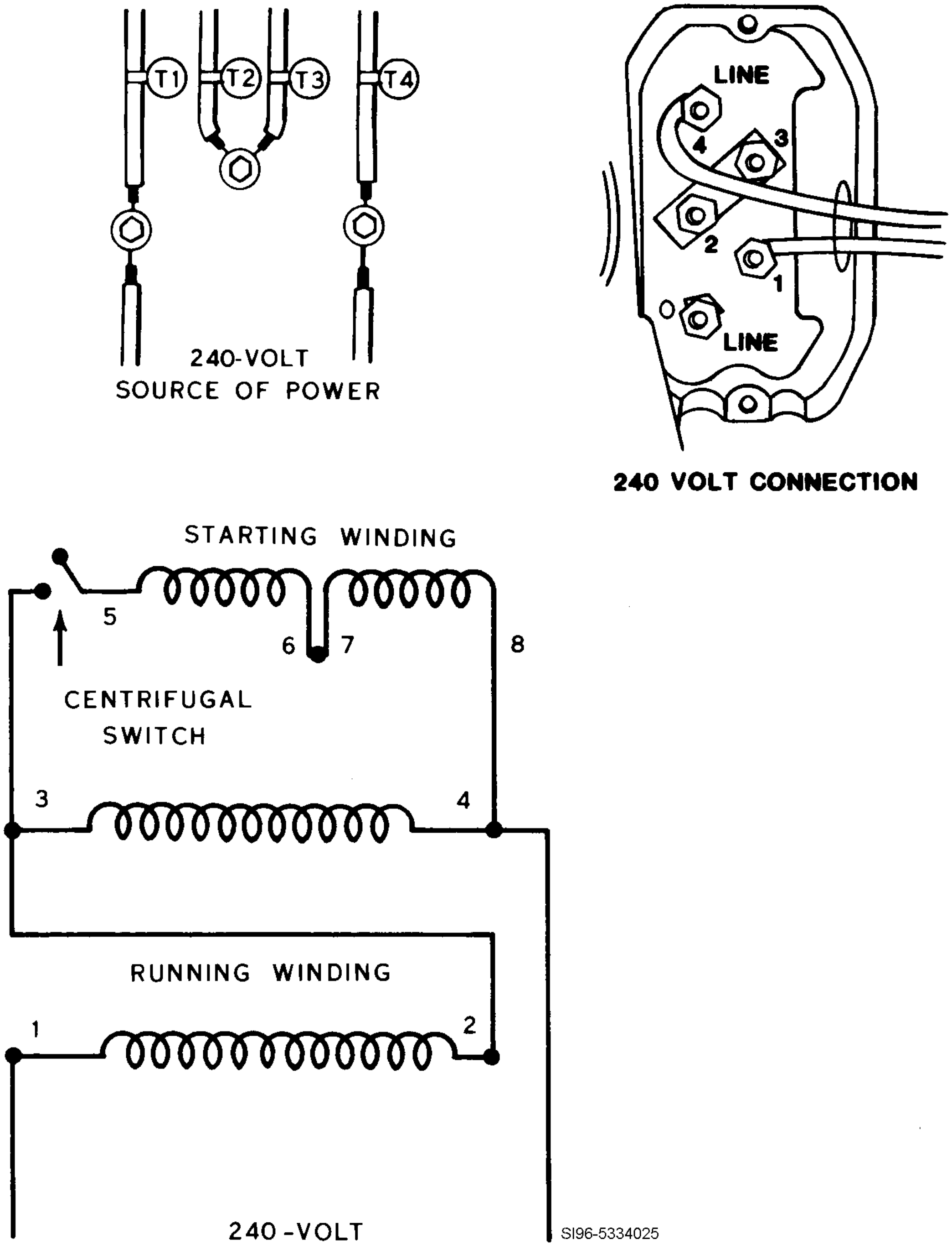


Figure 21, High-Voltage Connections

NOTE:
Figure 20 shows no external terminal leads for the start winding because the connections are made internally. Therefore, this motor is a dual-voltage non-reversible type. The start winding is always connected in parallel with the run winding. In a reversible motor, leads T5 and T8 are available externally in the terminal box.

- Splice T5 to T1 and connect to a conductor from the power source.
- Splice T8 to T4 and connect to the other conductor of the power source.
- To change rotation of a single-phase motor, change leads T5 and T8, which changes the current flow in the start winding and reverses the rotating magnetic field.

Step 12: Make motor connections (Single-phase, dual voltage, reversible motor for low voltage).

- Figure 22 shows how to connect the motor for 120-volt operation.
- Connect equipment grounding conductor(s) first.
- Second, connect grounded conductor(s).
- Splice T1 and T3.
- Splice T2 and T4.
- Splice T5 to T1 and T3, then connect to power source.
- Splice T8 to T2 and T4, then connect to the other power source conductor.
- To change rotation of a single-phase motor, change leads T5 and T8, which changes the current flow in the start winding and reverses the rotating magnetic field.

Step 13: Make final connections.

- Connect the conductors going to the power source to the load side of the control device.
- Test the motor for proper rotation before connecting the load.

SAFETY:
ALWAYS USE PROPER BLOCKING AND TAGGING PROCEDURES SO THE POWER CANNOT BE INADVERTENTLY TURNED ON WHILE YOU ARE WORKING ON THE SYSTEM. REMOVE ALL JEWELRY AND WEAR ANY TYPE OF PERSONAL SAFETY EQUIPMENT DEEMED NECESSARY, SUCH AS HARD

NOTE:
Ensure that your work is accomplished in a neat and workmanlike manner and that all connections are mechanically and electrically secure.

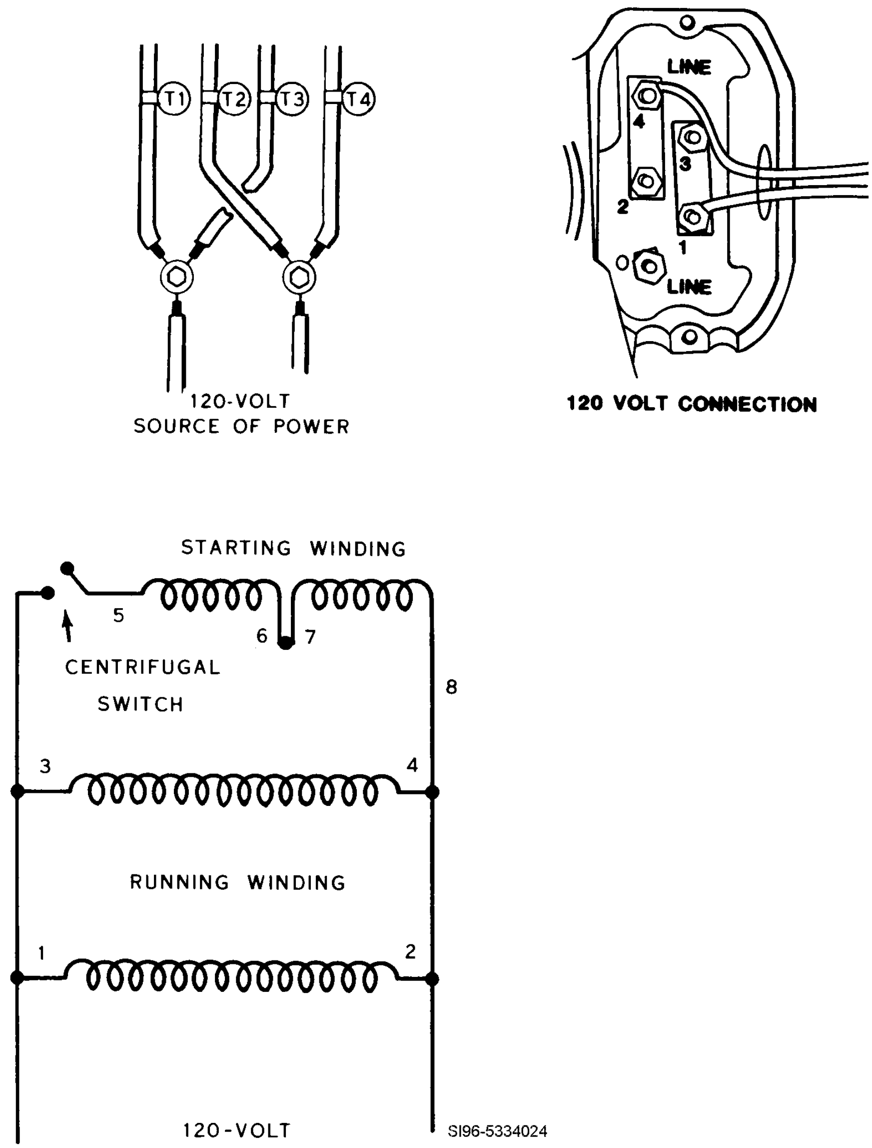


Figure 22, Low-Voltage Connections

Review Questions
for
Install Motors

Question	Answer
1. The general types of three-phase induction motors are ______ and ________.	a. Squirrel-cage, wire-wound. b. Induction, synchronous. c. Shaded pole, universal. d. Split phase, capacitor start.
2. What is the purpose of the rotor in an AC motor?	a. Serves to house the stationary windings b. It houses the bearings c. Drives the mechanical load. d. Completes the frame of the motor.
3. The two types of internal connections for a three-phase motor are wye and delta.	a. True b. False
4. How are the windings of a three-phase dual-voltage motor connected for high voltage?	a. Series b. Parallel c. Wye d. Delta
5. What windings are found in the split-phase motor?	a. Run b. Start c. Both a and b d. None of the above
6. The normally closed contacts of the centrifugal switch are in series with the run windings.	a. True b. False
7. A continuous duty motor means the motor is expected to carry the load for at least ___ hours or more.	a. 2 b. 3 c. 4 d. 5
8. For choosing protection devices you use the amperage listed on the motor's data plate.	a. True b. False
9. A conductor supplying a single motor must be able to handle ____ of the FLC.	a. 75% b. 100% c. 125% d. 150%
10. When connecting a delta motor for high voltage, which leads are connected to the power source?	a. 1, 2, 3 b. 1-7, 2-8, 3-9 c. 4, 5, 6 d. 4-7, 5-8, 6-9
11. How do you change the rotation to a single-phase reversible motor?	a. Switch any two power leads. b. Switch leads T5 and T8. c. Switch T1 and T2. d. A single-phase motor cannot be reversed.

INSTALL MOTORS

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee choose the appropriate motor for the job?		
2. Did the trainee calculate the full load current using the NEC?		
3. Did the trainee choose the correct fuse size?		
4. Did the trainee determine the correct conductor and conduit size?		
5. Did the trainee properly make connections for high or low voltage?		
6. Did the trainee check for proper rotation before connecting the load?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

MOTORS AND MOTOR CONTROL CIRCUITS

MODULE 21 AFQTP UNIT 2

INSTALL MOTOR CONTROL CIRCUITS (21.2.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

INSTALL MOTOR CONTROL CIRCUITS

Task Training Guide

STS Reference Number/Title:	21.2. – Motors and motor control circuits, install motor control circuits
Training References:	• CDC 3E051B, Vol. 2 • National Electric Code, article 430
Prerequisites:	• Possess as a minimum a 3E031 AFSC
Equipment/Tools Required:	• General tool kit
Learning Objective:	• Given equipment, install a motor control circuit
Samples of Behavior:	• Follow the required steps to install a motor control circuit • Know the safety requirements to install a motor control circuit
Notes:	
• Any safety violation will result in an automatic failure.	

INSTALL MOTOR CONTROL CIRCUITS

Background: In this unit, we'll discuss some of the common AC motor controllers. The term "controller" refers to any switch or device that normally starts and stops a motor. A controller can be very simple or very complex, depending on the situation. As an electrician, you'll be responsible for ensuring that motors and their controls are operating properly. In order to do this you'll need to understand how controls work.

Across-the-line controls are devices that start, stop, and usually protect a motor. To stop and start a motor, an across-the-line control must contain a device that makes and breaks contacts in the supply lines to the motor. In addition, the control normally provides some form of motor current protection. Across-the-line AC motor controls are generally of two types: (1) manual or (2) magnetic.

A manual control is a device; either hand or mechanically operated, for controlling a motor from a single point. Moving a switch or pushing a button does this. Each controller must be capable of starting and stopping the motor that it controls. The manual control can be a plain switch with or without overload protection. The term "overload protection" refers to a device sensitive to motor current. This device is designed to protect the motor windings by interrupting the current flow when an overload situation exists. Manual controllers control both single-phase and three-phase motors. Generally, they are limited to small horsepower applications.

You can use a toggle switch or light switch to control a small motor. It must be connected to open one of the ungrounded conductors in the circuit. To operate a 240-volt motor with two ungrounded conductors, only one ungrounded conductor is required to be opened. In a 120-volt circuit, only a single-pole switch is necessary to open the ungrounded conductor. A bathroom exhaust fan or garbage disposal operated by a toggle switch is a good example of this type of control. Remember that a toggle switch must be rated for 125% of the motor load. A branch circuit overcurrent protection device (which is the circuit breaker) protects the motor.

You use the fused safety switch or disconnect switch on small single-phase or three-phase motors. It operates on the same principle as the toggle switch. It is connected to open all ungrounded (or hot) conductors to the motor.

The schematic for a manual pushbutton controller with overload protection is shown in Figure 1. In this case, the controller is connected to a device that connects or disconnects both ungrounded conductors to the motor. It has a start and stop button that mechanically opens or closes the contacts. Pressing the start button closes both contacts and pressing the stop button opens both contacts A typical application of this type of control would be to control small machine tools.

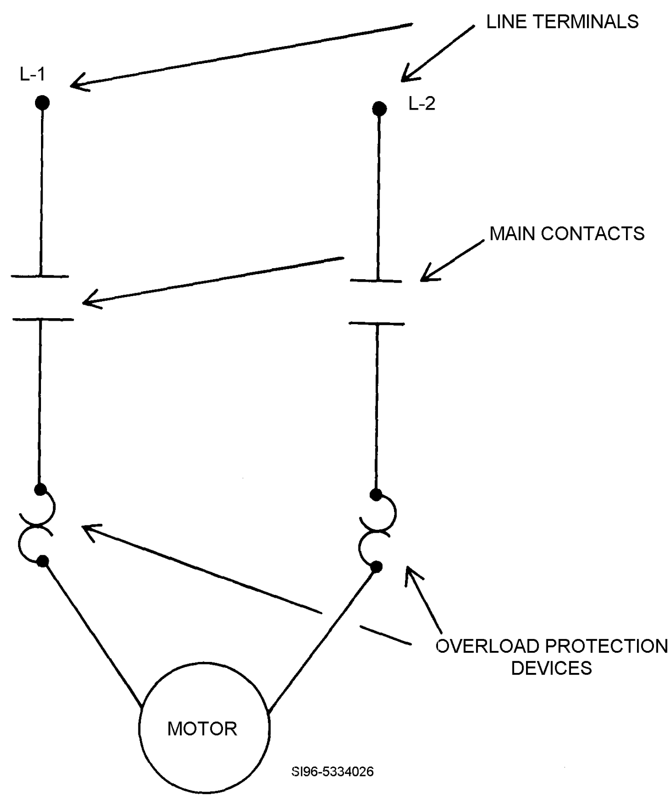


Figure 1, Schematic for A Single-Phase Manual Controller with Overload Protection

Manual controllers for three-phase motors have three separate line terminals. There is one for each ungrounded conductor. These three terminals connect internally to three separate sets of main contacts that manually open and close the circuit to the motor. When the controller has overload protection, it has an overload device installed in series with each main set of contacts. The overload devices respond to an overload condition (excess motor current) by opening all main contacts and disconnecting the motor just like the pushbutton controller did. Usually, the three line terminals are labeled L1, L2, and L3. These terminals are points at which the supply conductors are attached. Usually, the three load terminals (labeled T1, T2, and T3) are the points where the conductors supplying the motor are attached.

The drum control is a manual control that normally changes the rotation of a motor. The drum control is a lever-operated, three-position switch. The center position is usually the off position with the right and left positions forward and reverse respectively. Figure 2 shows a schematic of a three-phase drum control with its internal contacts. You see in the right half of the figure that the L1 contact feeds motor lead T1, L2 feeds motor lead T2 and L3 feeds motor lead T3. On the left side of the figure, the respective L1 and L2 motor lead contacts are reversed. L3 is still feeding T3. We have reversed two power leads to the motor. A single-phase motor can utilize the same drum control, but four or five conductors are required from the motor to the control depending on the requirement for high or low voltage operation. Always refer to the cover of the control for a schematic of the connections required for a specific motor installation.

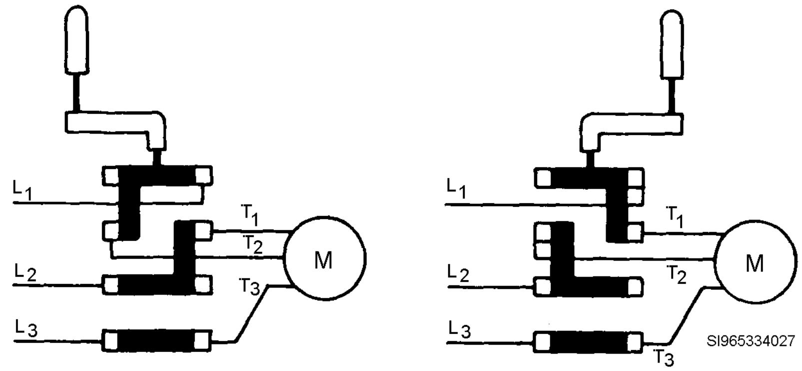


Figure 2, Reverse And Forward Drum Control Positions

Controllers usually have two basic characteristics:

- When activated they energize and deenergize the motor.
- If an overload occurs in the motor circuit, the circuit protection should open or the built-in overload contacts should open.

Magnetic Control

Another across-the-line motor-control device that you can use is the magnetic control. This control, or starter, is operated magnetically and connects the motor across the line using an electromagnet to close the main or load contacts. This type of starter provides a safe, convenient, and economical means for controlling an electric motor. Magnetic controls are the most commonly used starters and offer the advantage of being controllable with an automatic device or a remote control. A magnetic control, commonly called an across-the-line magnetic starter, has two main sections: the contactor and the overload relay.

The operation of an across-the-line magnetic starter is fairly simple. When the electromagnetic coil is energized, it sets up a magnetic field attracting the armature. When the armature moves toward the electromagnet, the movable contact connects with the stationary contact. This completes the circuit to the motor and the motor starts. When the switch in the circuit that supplies power for the electromagnetic coil is opened, the coil is de-energized, causing a loss of the magnetic force and spring tension or gravity pulls the contacts apart. Other magnetic line starters have more contacts and motor overcurrent-protection relays. The across-the-line magnetic starter contains two electrical circuits: the load circuit and the control circuit. The load circuit contains the main or load contacts, the line terminals, load terminals, and the heater coil portion of the overload relay. The load circuit is the determining factor as to the size of motor it controls. It must have a larger rating than the connected motor. The control circuit contains the holding coil, reset contacts of the overload relay, and the auxiliary contacts.

The auxiliary contacts or holding contacts are located also on the contactor. They are joined usually by an insulated connecting bar so that all contacts, both main and auxiliary, close when the holding coil becomes energized. The contactor also provides terminals for the attachment of

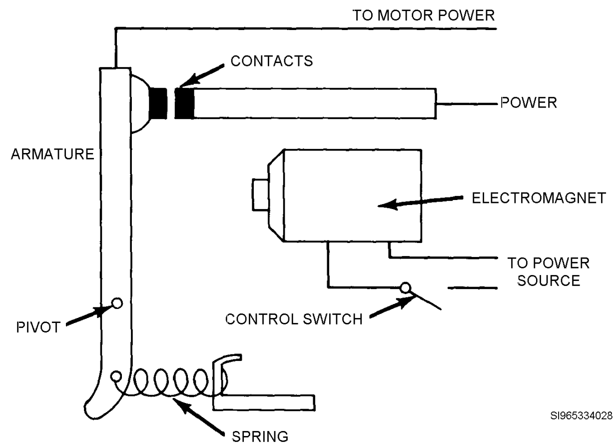


Figure 3, Magnetic Contactor

the supply conductors. These terminals usually are identified with the letter "L." For example, terminals L1 and L2 are the supply conductor terminals of a single-phase magnetic starter. The auxiliary contacts also have terminals. Auxiliary terminals attach the conductors from control devices and are identified with the numbers 2 and 3.

Reversing Starters

You use reversing starters when there is a need to change rotation of three-phase motors. As stated before, in order to change rotation of a three-phase motor you reverse any two power leads. This is done to achieve the correct rotation on installation. If there is a need for a piece of equipment to change rotation frequently the reversing starter is the most practical way. The reversing starters consist of two separate contactors. One of the contactors is used for the forward rotation of the motor and the other for the reverse rotation. These two contactors must never energize at the same time because this will produce a direct short. To keep this from happening, the contactors are set up with an interlocking system. The two types of interlocks are mechanical and electrical. The mechanical works in a way that mechanically holds one contactor open while the other one energizes. The electrical type (by the use of contacts) keeps one control circuit from energizing when the other contactor is energized. Some manufacturers employ both types of interlocks on the same reversing starter. Of course, this is an additional safety backup.

Reduced Voltage Starters

The purpose of reduced voltage starters is to reduce the high starting current draw and starting torque of motors. One easy way to start a motor using reduced voltage is with the use of resistors. The resistors are installed in series with the power leads that tie directly to the motor. Once the motor starts, there is a set of contacts that are parallel with each resistor that closes once the motor reaches a certain rpm. The closing of the contacts can be operated automatically or manually. Once closed there is full line voltage. This starter allows the motor to smoothly accelerate, have a lower torque, and a gradual increase in speed.

The autotransformer is a reduced voltage starting method that provides better starting torque that the primary resistor. The transformers are tied into the load side of the magnetic starter (T1, T2, and T3). These transformers have various taps. The taps are labeled 50, 65, 80, and 100 percent. The equipment it is attached to will determine the tap you use. Once you have determined the correct tap to use, make an operational check on the equipment. If the equipment does not have sufficient starting torque, increase your tap setting and make another check. When the motor starts, a time-delay relay will bring in the full line voltage, and the motor continues at this voltage until it is turned off.

The star delta arrangement should be used on equipment that needs a long, slow starting process. This includes equipment such as big chillers, fans, pumps, and blowers. This type of reduced starting does not use resistors or transformers. Instead, the motor is wired to start in the star configuration and end up running in delta. The motor leads are accessible externally and are tied to contactors that will sequence the start and run of the equipment. Overload protection is wired to carry the motor-winding current.

Over Load Protection

Nearly all magnetic starters are equipped with an overload device or overload relay to protect the motor from excessive current in a running situation. Current-sensitive elements of the overload relay are connected either directly or indirectly and act to de-energize the starter and stop the motor when excessive current is drawn. The basic requirement for overload protection is that the motor be allowed to carry its full-rated load and yet prevent any prolonged or serious overload. When a motor is overloaded mechanically, motor current increases, which in turn increases the temperature of the motor and its windings. The same increases in current and temperature can be caused by the loss of a single-phase on three-phase motors or a partial fault in the motor windings. To give full overload protection we need only to sense or measure the current draw by the motor and break the circuit when this current exceeds the rated value for the motor.
There are three basic types of overload relays; thermal, magnetic, and solid state. The first unit, thermal, is sensitive to heat. This unit may be a bimetallic type or melting-alloy type. The second type uses a magnetic device and is sensitive to motor current. Lastly, the solid state units use a current sensing device to monitor the load and an electronic trip unit to open the circuit. Regardless of the type used, it is activated by an excessive current flow in the motor. When one of these devices detects an excessive current, it reacts by opening a set of reset contacts that are in series with the holding coil. This causes the holding coil to de-energize and open the main or load contacts. Overload relays must be reset automatically or manually after each tripping. To better understand the overload relay, let's look at each type individually.

Thermal relays are usually the bimetallic or melting-alloy types. The bimetallic type is constructed of two dissimilar metals that when heated bend due to the different rate of expansion of the two metals. A heating element in the motor-line circuit generates the heat necessary to activate the strip. Current in excess of the desired amount causes deflection of the bimetallic strip to the extent that the contacts spring apart opening the holding coil circuit. Figure 4 is a line drawing of a bimetallic overload relay. A reset button is depressed to reactivate the mechanism when the strip has cooled to operating tolerance.

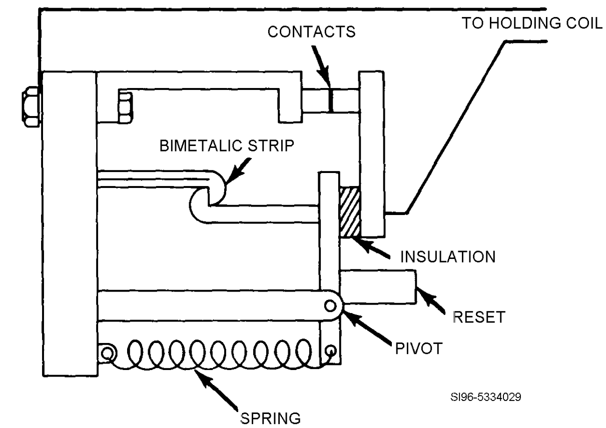


Figure 4, Bimetallic Overload Relay

The melting-alloy overload relay employs a heating coil connected in the motor-line circuit. See Figure 3. The heat caused by excessive current in the motor circuit melts the metal alloy (similar to solder) releasing the spring-loaded shaft. The shaft is then capable of turning. This permits the reset contacts to open the coils control circuit. When the alloy has cooled and solidified sufficiently, the motor may be restarted by depressing the reset button. An example of the melting-alloy principle is shown in Figure 5.

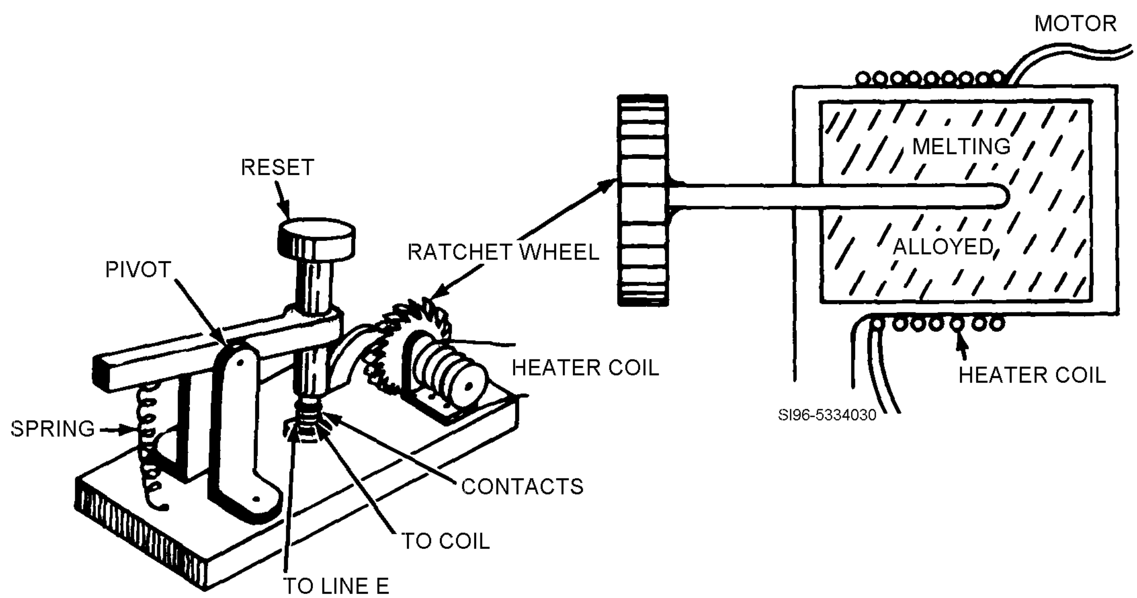


Figure 5, Melting-Alloy Thermal Overload Relay

The magnetic overload relay has a coil, a plunger, a dashpot, and a set of contacts (Figure 6). The coil is connected in series with the motor. When a determined amount of current passes through the coil, the magnetic field pulls up the plunger causing the contacts to open. By adjusting the length of the plunger, the amount of current required to pull the plunger up can be varied. An oil-filled dashpot is added to provide a time delay. A plate on the bottom of the plunger is submerged in the oil and acts as a piston. The plate has holes in it that can be adjusted in size to change the time delay. When the coil pulls the plunger up, the oil must flow through the hole in the plate as the plunger rises. By changing the size of the hole, the time delay can be increased or decreased. Quick tripping is obtained through the use of a light grade dashpot oil.

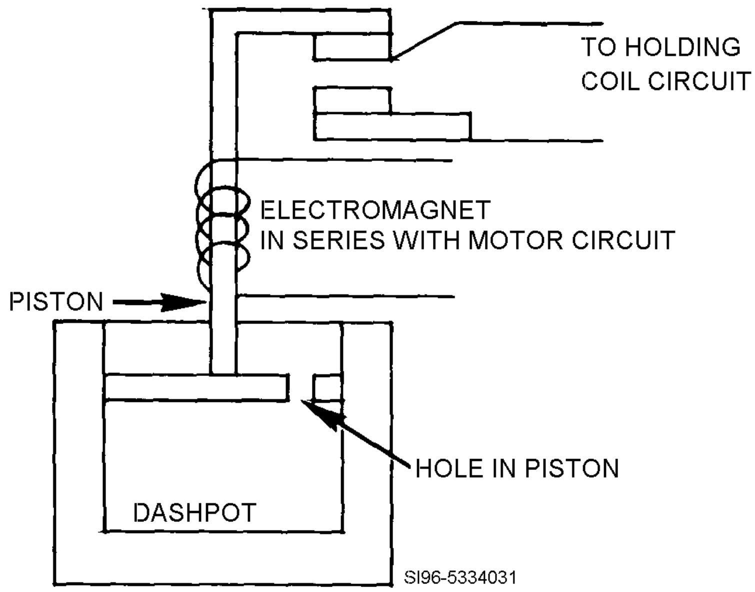


Figure 6, Magnetic Overload Relay

The overload relay size is determined by the full load current rating of the motor it protects. When selecting the heaters to protect a motor, you should check the motor data plate to find the full load current rating. Each manufacturer normally puts a heater selection table in the controller cover. Heaters are not identified by amperage, but by the manufacturer's catalog number. By using the full load current of the motor and referring to the manufacturer's table, you can select the proper heater. The overload relay also provides terminals for the attachment of the supply conductors. These terminals usually are identified with the letter "T." For example, terminals T1 and T2 are the load terminals of a single-phase magnetic starter and provide a point to connect the conductors supplying the motor.

The solid state overload relay performs the same job as the thermal and magnetic relays. It monitors the current drawn by the motor and when it is excessive, it will open power to the operating coil. Unlike the other methods the solid state OL doesn't require mechanical moving parts. This device can also be purchased with an adjustment range for different full load currents. This method provides the most accurate and repeatable operation.

Control Circuits

The control circuit is the portion of the magnetic starter that performs the function of starting, stopping, controlling, and protecting a motor. All control circuits require some kind of master switch to energize and deenergize the operating coil. Generally, these devices are connected using a two or three-wire circuit. A two-wire control circuit receives its power from the incoming leads to the starter. The basic control circuit is a series circuit from L1. It goes through the control device, the holding coil, and the overload reset contacts. It returns to L2 or to neutral depending on the voltage rating of the coil. Figure 7 shows a diagram of a two-wire control circuit using a single-pole toggle switch as a control device. The magnetic coil is connected to the line on one side through the overload-reset contacts and on the other side through the contacts of the toggle switch. As long as the contact of the toggle switch remains closed, the contactor is energized. When the contacts of the toggle switch open the coil is de-energized and the contactor opens. Notice that when an overload occurs, the overload relay reset contacts will open and this removes the coil from the circuit. When the overload relay is reset, the contactor will again immediately pick up because the toggle switch is in the closed position.

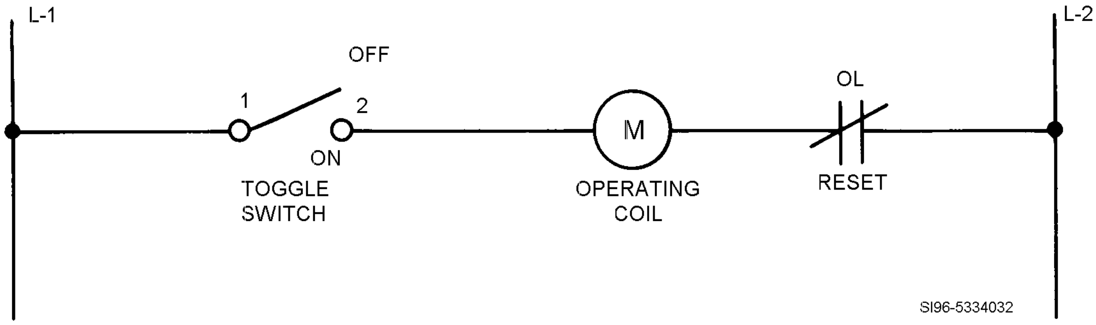


Figure 7, Two-Wire Control Circuit

A three-wire control circuit also receives its power from the incoming leads to the starter. This circuit uses the same components as the two-wire circuit, except that the auxiliary contacts and a momentary stop-start station are introduced. Remember, the holding coil controls the auxiliary contacts, and they close and open at the same time as the main contacts. The stop-start station is a manual control device containing a start and stop button. When the start button is pressed, a normally open set of contacts is closed and when the stop button is pressed, a normally closed set of contacts is opened. Spring action returns the buttons to their original position when finger pressure is removed. To operate a magnetic starter by a stop-start station connect the coil to the stop-start station so that when the start button is pressed, the coil becomes energized. When the stop button is pressed, the holding coil circuit is opened. A diagram of a typical across-the-line magnetic starter equipped with a thermal overload relay and connected to a stop-start pushbutton station is presented in Figure 8. When the start button of the station is pressed, it completes the circuit from L1 through the normally closed contacts of the overload relay and through the holding coil to L2. Thus, the coil is energized and the main contacts are closed, connecting the motor across the line. This action also closes the auxiliary contacts which keep the coil energized after the finger is removed from the start button. Pressing the stop button opens the control circuit and causes all contacts to open. If a prolonged overload should occur during the operation of the motor, the overload relay contacts open and de-energize the holding coil. If an overload condition has caused the relay to trip, it is necessary to reset the relay contacts by hand before the motor can be restarted.

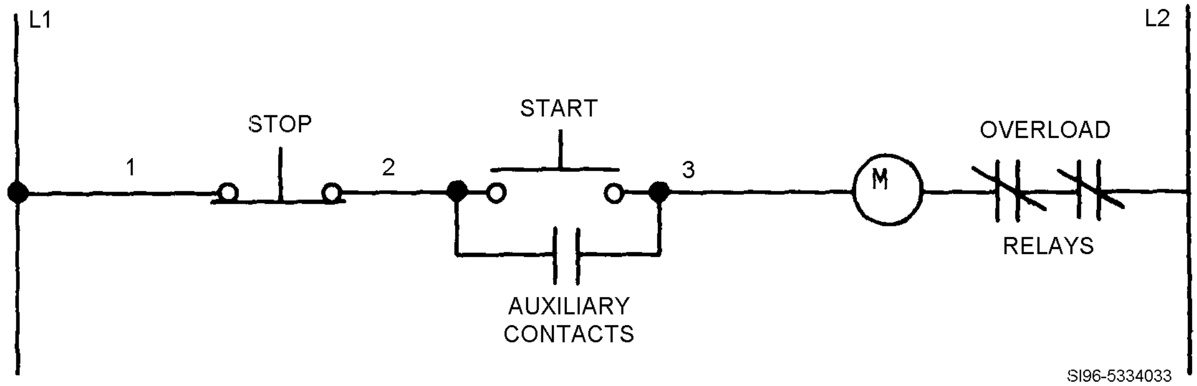
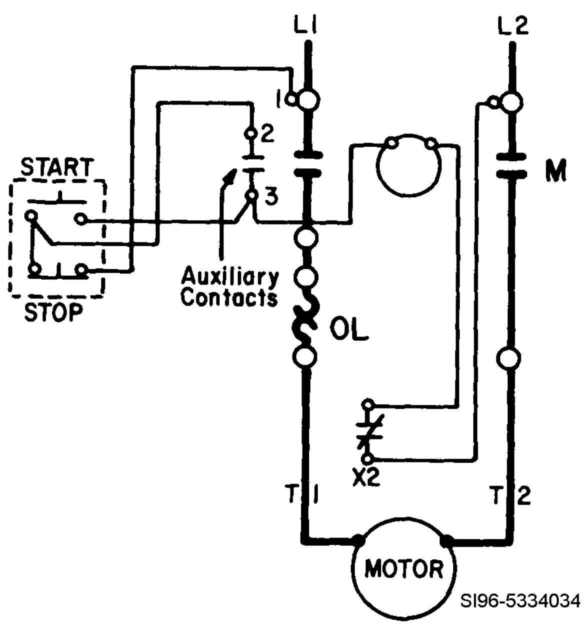


Figure 8, Three-Wire Control Circuit

To control a single-phase motor, a single-phase across-the-line magnetic starter must be used. The single-phase starter must have line terminals L1 and L2 for the connection of the (line) conductors and T1 and T2 for the connection of the motor (load) conductors. A motor-running overload protection device, such as an overload relay, thermal or magnetic, must be installed. In accordance with the National Electrical Code (NEC), there must be one overload device installed in either ungrounded conductor for a single-phase AC motor. For example, a 208-volt, 2-wire, 1-phase system has two ungrounded conductors attached to L1 and L2. One overload device must be installed in series with either one of these ungrounded conductors. You see in Figure 9 a diagram of a single-phase across-the-line magnetic starter.

Figure 9, Single-Phase Across-The-Line Magnetic Starter



To control a three-phase motor, a three-phase across-the-line magnetic starter must be used. The three-phase starter will have line terminals L1, L2, and L3 for the connection of the line conductors and T1, T2, and T3 for the connection of the motor load conductors. Like the single-phase controller, the three-phase magnetic starter must also have an overload relay with thermal or magnetic cutouts. The NEC® requires that one of the previously mentioned overload devices be installed in each ungrounded phase of the starter. For example, a 208-volt, 3-wire, 3-phase system must have an overload device in each ungrounded phase. This means there are three devices. Figure 10 shows a diagram of a three-phase across-the-line magnetic starter.

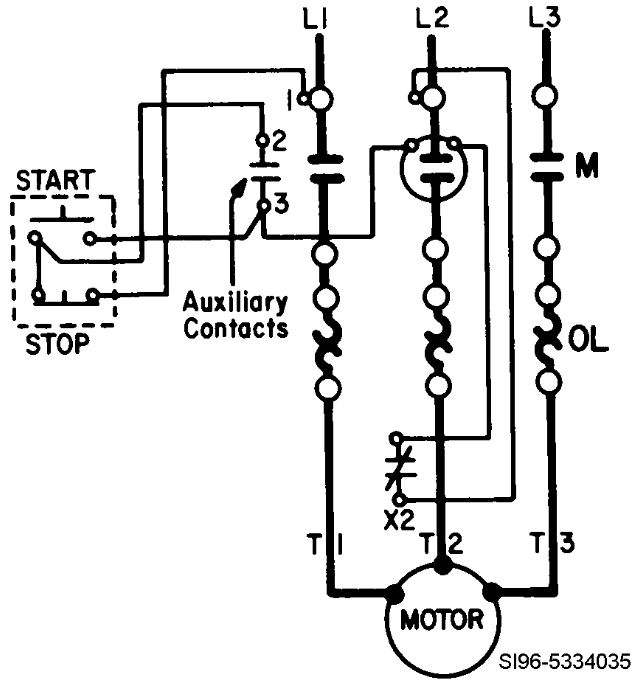


Figure 10, Three-Phase Across-The-Line Magnetic Starter

Automatic devices can be used to control or operate a magnetic starter. They would be installed like the toggle switch in Figure 10. Some of the most common types are:

- **Float switches.** Often fluid levels are controlled by the use of a float switch. This switch is a set of contacts that are opened or closed mechanically by a lever and float assembly. By using motor-driven pumps controlled by a float switch, the level of liquid can be increased or decreased automatically. An example of a common use of float switches is to control the water level in water towers.
- **Pressure switches.** Pressure switches control the pressure of gases, air, and liquids within a desired range. For example, a pressure switch controls a motor on an air compressor.
- **Thermostats.** The thermostat is a device sensitive to temperature and is widely used in heating and cooling systems to control the system.

One of the newest methods of motor starting and speed control is the solid state system. At the center of solid state systems is a silicon-controlled rectifier (SCR). The SCR controls the voltage, current and torque during the motor's acceleration.

In conjunction with SCR controller is the frequency inverter, by adjusting the frequency down from the 60 Hz, the motor will run slower. A frequency greater than 60 Hz can also be developed allowing the motor to run at maximum speed. These starters must be sized to the motor they are to control.

This method of starting provides for a smooth, one step acceleration. It is best used with loads such as conveyor pumps, and compressors etc. The incentive to these electronic starters is their long life and reduced energy cost for large motor operation, and speed control during start-up and run operations.

To perform the task, follow these steps:

Step 1: Select controller.
- Choose the type of controller that best suits your needs.
- Choose the enclosure for the controller depending on the location it is being installed.

The motor controller and related equipment must comply with the same requirements as the motor. If the motor enclosure must be explosion-proof, then the controller, when installed under the same conditions, must be explosion-proof. The enclosure must be adequate for the location in which it is installed. The National Electric Manufacturer's Association (NEMA) has assigned enclosure numbers to identify the types of enclosures used:

Type 1	Open or general purpose
Type 3	Weather protected
Type 3R	Rain tight
Type 4	Moisture protected
Type 6	Liquid tight
Type 7	Hazardous vaporproof
Type 9	Hazardous dustproof
Type 7 and 9	Hazardous vapor and dustproof
Type 11	Oil emerged
Type 12	Oiltight, dusttight

- Any additional information you need might be found in Article 430 of the NEC®, entitled "Motors, Motor Circuits, and Controllers."

Step 2: Mount controller.
- Mount the device in the best location to control the motor.
- Install the conduit and wiring using the NEC to find the proper sizes.
- All fittings must be tight and of the proper type.
- Boxes must be mounted correctly and all openings must be sealed.

NOTE:
There are too many different kinds of control devices to go into detail on the installation of all of them. We will be discussing the installation of a three-phase across-the-line magnetic starter controlled by a stop-start station. Most control devices are very similar in their installation. If you are installing a different type of control, it should come with a schematic to help in the installation.

Step 3: Select heater size.

- The overload relay size is determined by the full load current rating of the motor it protects.
- Check the motor data plate to find the full load current rating.

NOTE:
Each manufacturer normally puts a heater selection table in the controller cover. Heaters are not identified by amperage, but by the manufacturer's catalog number. By using the full load current of the motor and referring to the manufacturer's table, you can select the proper heater. The overload relay also provides terminals for the attachment of the supply conductors. These terminals usually are identified with the letter "T." For example, terminals T1 and T2 are the load terminals of a single-phase magnetic starter and provide a point to connect the conductors supplying the motor.

Step 4: Isolate circuit.

- Block and tag power source.

Step 5: Make connections on start circuit.

- Use Figure 8 to help you find the locations of connection points.
- Connect the line from the start switch terminal of the stop/start station to the auxiliary contact terminal #3 on the magnetic starter.

Step 6: Make connections on control circuit.

- Connect terminal #3 from the auxiliary contact to one side of the coil on the starter.
- Connect the other side of the coil in series through each normally closed (NC) overload contact and then to the line side of L2 (240V coil).

Step 7: Make connections on holding circuit.

- Connect terminal #2 from the auxiliary contact of the starter to the jumpered side of the stop/start station.

Step 8: Make connections on load circuit.

- Connect the motor leads to the terminals at the bottom of the starter marked T1, T2, and T3.

Step 9: Make connections on power circuit.

- Connect the conductors coming from the power source to the top of the across the line magnetic starter on the terminals marked L1, L2, and L3.

- Connect the line from terminal L1 on top of the magnetic starter to the stop switch of the stop/start station.

SAFETY:
REMEMBER, WHEN MAKING ALL CONNECTIONS, BE SURE THE POWER HAS BEEN SHUT OFF, BLOCKED, AND TAGGED PROPERLY.

Step 10: Test the circuit.

- Recheck all your connections to ensure they are mechanically and electrically secure.
- Check the area to make sure it's clear of personnel before you perform the operational check.
- Energize the circuit.
- Test all the control devices for proper operation.
- After completing the operational check you can connect the motor to its load.

Review Questions
for
Install Motor Control Circuits

Question	Answer
1. What are the two general types of across-the-line AC motor controls?	a. Fused safety switch and disconnect switch b. Manual and magnetic c. Drum and resistor d. None of the above
2. A manual control is a device that is operated magnetically using an electromagnet and is used to control a motor from a single point.	a. True b. False
3. What are the two basic types of overload relays?	a. Bimetallic and thermal b. Thermal and dashpot c. Thermal and magnetic d. Bimetallic and melting alloy
4. How can you find the full load current rating of a motor?	a. Check with a multimeter b. Using Ohm's law formula E=IR c. Check the motor data plate d. All of the above
5. Name an automatic device used to control or operate a magnetic starter.	a. Pressure switch b. Float switch c. Thermostat d. All of the above
6. The start circuit runs from the start switch terminal of the stop/start station to the auxiliary contact terminal ___ on the magnetic starter.	a. #3 b. #2 c. L3 d. L2
7. In the control circuit of a magnetic starter, one side of the coil is connected in series to each normally open overload contact and then to the line side of L2.	a. True b. False
8. Which terminals on the magnetic starter do you connect the motor leads to?	a. L1, L2, L3 b. They are connected to one side of the coil c. The load side of the auxiliary contacts d. The load side of the overload relay

INSTALL MOTOR CONTROL CIRCUITS

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee choose the proper controller for the job and the location?		
2. Did the trainee select the proper heater size?		
3. Did the trainee block and tag the power source?		
4. Did the trainee properly connect the start circuit?		
5. Did the trainee properly connect the control circuit?		
6. Did the trainee properly connect the holding circuit?		
7. Did the trainee properly connect the load circuit?		
8. Did the trainee properly connect the power circuit?		
9. Did the trainee test the circuit?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

Air Force Civil Engineer

QUALIFICATION TRAINING PACKAGE (QTP)

REVIEW ANSWER KEY

For

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 21

MOTORS AND MOTOR CONTROL CIRCUITS

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

INSTALL MOTORS

(3E0X1-21.1.)

Question	Answer
1. The general types of three-phase motors are ______ and ________.	b. Induction, synchronous
2. What is the purpose of the rotor in an AC motor?	c. Drives the mechanical load.
3. The two types of internal connections for a three-phase motor are wye and delta.	a. True
4. How are the windings of a three-phase dual-voltage motor connected for high voltage?	a. Series
5. What windings are found in the split-phase motor?	c. Both a and b
6. The normally closed contacts of the centrifugal switch are in series with the run windings.	b. False
7. A continuous duty motor means the motor is expected to carry the load for at least ___ hours or more.	b. 3
8. For choosing protection devices you use the amperage listed on the motor's data plate.	b. False
9. A conductor supplying a single motor must be able to handle ____ of the FLC.	c. 125%
10. When connecting a delta-connected motor for high voltage, which leads are connected to the power source?	a. 1, 2, 3
11. How do you change the rotation to a single-phase reversible motor?	b. Switch leads T5 and T8

INSTALL MOTOR CONTROL CIRCUITS

(3E0X1-21.2.)

Question	Answer
1. What are the two general types of across-the-line AC motor controls?	b. Manual and magnetic
2. A manual control is a device that is operated magnetically using an electromagnet and is used to control a motor from a single point.	b. False
3. What are the two basic types of overload relays?	c. Thermal and magnetic-
4. How can you find the full load current rating of a motor?	c. Check the motor data plate
5. Name an automatic device used to control or operate a magnetic starter.	d. All of the above
6. The start circuit runs from the start switch terminal of the stop/start station to the auxiliary contact terminal ___ on the magnetic starter.	a. #3
7. In the control circuit of a magnetic starter, one side of the coil is connected in series to each normally open overload contact and then to the line side of L2	b. False
8. Which terminals on the magnetic starter do you connect the motor leads to?	d. The load side of the overload relay